Institution: University of Bristol
Unit of Assessment: 6: Agriculture, Food and Veterinary Sciences
1. Unit context and structure, research and impact strategy

Following REF2014, the University of Bristol (UoB) undertook a major strategic review of biomedical and life sciences research to catalyse and empower excellence for the current REF cycle and beyond and, with respect to UoA6, to enhance 'One Health Agenda' links between plant, animal and medical science. Major developments for UoA6 collaborations include three of the University Research Institutes (URIs, Institutional-level Environment Statement: REF5a, and section 4): the Cabot Institute for the Environment; the Elizabeth Blackwell Institute for Health Research (EBI); and the Jean Golding Institute for Data Science and Data-Intensive Research (JGI), as well as the Bristol Population Health Science Institute (Bristol-PHSI, a Specialist Research Institute including ALSPAC and the MRC Integrative Epidemiology Institute, UoA2). To lead these changes Iredale (UoA1) was appointed PVC both for Health and Life Sciences, and Faculty re-organisations brought key groups together. Bristol Veterinary School joined Medicine, Dentistry and Anatomy to form the Faculty of Health Sciences (Dean: Norman, UoA1). The Faculty of Life Sciences (Dean: Tavare) combined the Schools of Biological Sciences and Psychology with the former Faculty of Biomedical Sciences. To maximise the opportunity created by these moves, the scientific research strategy across the two faculties is defined and facilitated by the Health and Life Sciences Research Strategy Committee, jointly chaired by the Research Directors for the 2 faculties. This committee provides over-arching strategic vision for research and ensures that appointments are delivered to maximise research delivery and impact for all schools. This structure provides tight coordination between medical, veterinary and fundamental sciences, and is further facilitated by the appointment of **Dowsey**, a data scientist with a joint appointment in Bristol Medical School (BMS), as Research Director for the Veterinary School and also recently as Faculty co-Director of Enterprise and Innovation.

The success of this approach is demonstrated by UoA6 researchers' ability to pivot rapidly in early 2020 and contribute our facilities and expertise in zoonoses, One Health and epidemiological modelling to tackling COVID-19, part of an initiative funded by the EBI (**Brooks Pollock**, membership of SPI-M and SPI-B; **Bailey**, membership of BBSRC COVID-19 funding panels; Turner, recommendations submitted to SAGE; Bristol's interdisciplinary COVID-19 research group, UNCOVER, **Cogan**, **Mann**, **Vidana Mateo**).

1.1. Overview of Research Policy and Structure

The focus of research in this UoA is on the interface between animal, human and planetary health ('One Health'). The goals of our research are to improve the immediate and future health of human and animal populations by:

- increasing sustainable production of healthy, high welfare food while supporting recovery of endangered environmental resources (e.g. **Wall** 2018 Agr. Ecosys. Env.);
- ensuring sustainable use of medicines in human and animal populations (e.g. **Reyher** 2016 Zoon. Pub. Health), a cornerstone of the wider UoB multi-disciplinary approach to antimicrobial resistance (AMR);
- reducing the impact of bacterial, viral and parasitic zoonotic diseases on human and animal populations (e.g. **Brooks Pollock** 2015 Proc Royal Soc B);

- translating new developments across fundamental research, human and animal medicine into management and therapeutic approaches which enhance the quality of life of animals and humans (e.g. **Hezzell** 2020 PNAS).

Our research is strengthened by the overlap between these 4 goals, and by the need to engage multiple disciplines to address the important questions. Interdisciplinarity is reflected by the inclusion of staff from the Faculties of Health and Life Sciences as follows.

- Bristol Veterinary School (BVS) focusing on: animal behaviour and welfare; infection, inflammation and immunotherapy; AMR; and clinical research.
- School of Biological Sciences (SoBS) groups working on: fundamental and applied aspects of parasitic infections in humans, animals and plants (**Gibson**, **Wall**; English, McGregor, Foster in UoA5); genomics of globally important crops (Barker, UoA5); and pollinators (**Rands**).
- School of Anatomy (SoA) working on: neuroendocrinology (**Tortonese**); and developmental biology (**Itasaki)**
- Joint appointments with Rothamsted Research's North Wyke Farm Platform BBSRC National Capability (**Lee**, **Takahashi**, **Enriquez Hidalgo**).

1.2. Strategic research structure

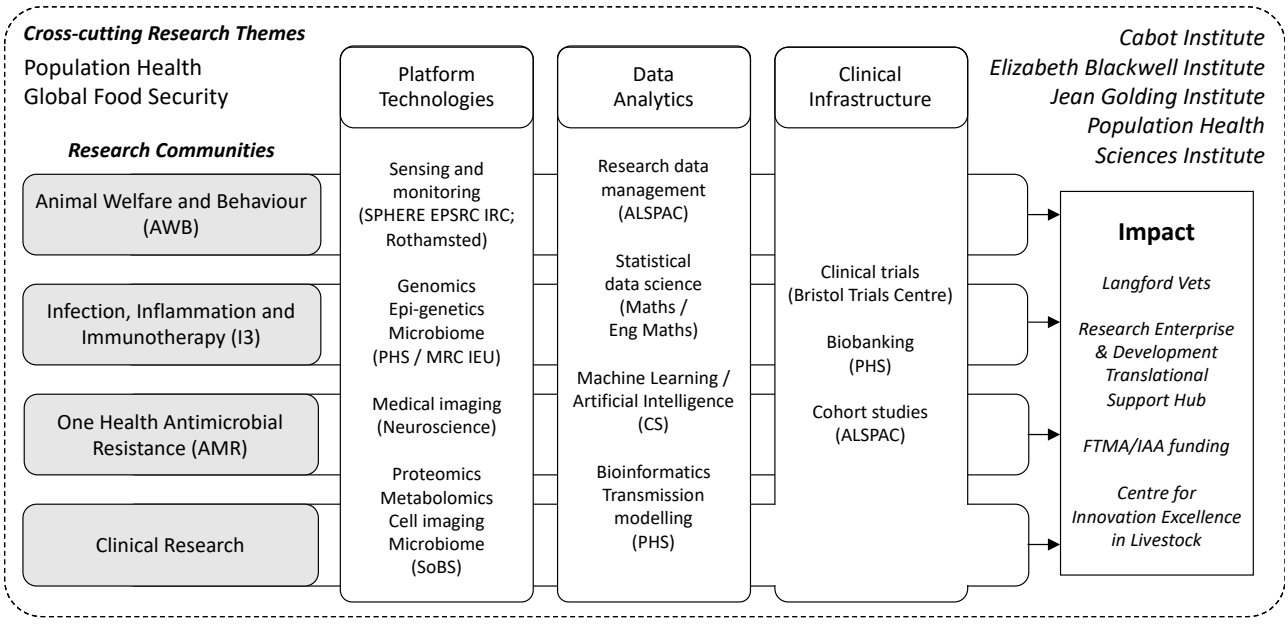

Figure 1: Strategic research structure for University of Bristol UoA6

As part of our new research strategy, UoA6 research was coalesced into two strategic, cross-cutting themes and four research communities of key excellence (Figure 1). The themes **Population Health** and **Global Food Security** channel our existing interdisciplinary research to align with strengths and institutes across the University, creating direction and critical mass to address key national and global challenges. Both themes share our underpinning research pipeline framework that facilitates access to cutting edge **Platform Technologies** and **Data Analytics**, large-scale **Clinical Infrastructure**, and expert support for generating sustainable **Impact**. Coordination is provided by theme leads, who work with all staff to maximise focus and synergy, and to maintain awareness of developing areas of global importance.

The new structures mean that UoA6 researchers collaborate widely across Schools and Faculties and contribute significantly to research returned in other UoAs, thus representing truly interdisciplinary, team science approaches to One Health challenges. Direct income attributed to UoA6 staff across these themes totaled **£18.9m** during the assessment period, predominantly from UKRI, and UoA6 staff were also involved in many more awards returned in UoAs 1, 2 and 5.

Population Health (lead, Reyher) takes a population-based view of the drivers of health and disease. The theme tightly integrates with both EBI and Bristol-PHSI (UoA2); **Reyher** sits on the PHSI Steering Group, which builds on the University's international reputation for research into the determinants and consequences of ill health. Key programmes and impact fundamentally underpinned by this theme's cross-faculty and transdisciplinary structure include:

- discovery science in molecular and genetic epidemiology (**Gibson** PloS NTD, 2015; **Cogan** 2016 Nature Genetics);
- innovative field studies (**Mendl** 2014 Biology Letters);
- policy-influencing and assessment activities (**Brooks Pollock** 2014 Nature, 2015 Proc Royal Soc B; **Sanchez-Vizcaino Buendia** 2017 Epidem Inf; **Reyher** 2016 Zoon Public Health);
- questions about health and welfare in both animal and human populations (**Turner** 2020 BMJ Global Health; **Turner** 2020 Lancet Inf. Dis.);
- our HDR-UK South-West Better Care Partnership (UoA2 £1.2m, Bristol-led, with Exeter & Bath), which integrates UoA6 expertise through an AMR theme led by Associate Directors **Dowsey** and **Turner**.

Global Food Security (lead, Bailey) addresses the issue of sustainable food production. Our transdisciplinary expertise has enabled us to champion the role of farm animals in truly sustainable, rationally designed, mixed agricultural systems validated by full life-cycle analysis (**Eisler, Tarlton, Lee** 2014 Nature). This theme closely interfaces with the Cabot Institute and its focus on 'living with environmental uncertainty' (in particular its Food Security theme) as well as our strategic partners Rothamsted Research. Our research includes fundamental sciences of animal health, welfare and disease, through their integration into food chains (ICS **Knowles**) to the effects on human health (**Tarlton** 2015 Poultry Science), where close synergy with BMS and EBI is key. Programmes underpinned by this theme's cross-faculty structure include:

- identifying solutions for sustainable food production across high-, middle- and low-income countries (**Takahashi** 2018 Nature Sustainability), *e.g.* the use of insect protein for animal feed (**Tarlton**, £571K);
- demonstrating that these solutions can maintain the welfare needs of livestock, even across LMIC countries (**Whay** 2015 PloS One);
- the development of agricultural sustainability metrics that are robust across multiple rainfall zones (**Escobar-Tello**, £1.6m).

The Research Pipeline: The latest platform technologies, data analytics and clinical infrastructure expand our ability to answer the important questions in One Health. Transdisciplinary collaboration has been key, for example with JGI's novel data analytics supporting our instrumented farm platforms and collaborations with strategic partners Rothamsted Research North Wyke. Recent joint appointments with Population Health Sciences (**Dowsey**) and Computer Science (**Talas**, **Fennell**) have been targeted at the use of high-throughput data generated by

cutting edge platform technologies (*e.g.* animal sensing and monitoring, imaging, 'omics including microbiome), and also at new analytics and AI in an interdisciplinary environment:

- new data science methodology and Bayesian models for interpreting biomedical proteomics and metabolomics data (**Dowsey**, £974k; Nature Comms Biol 2019);
- vision-based AI methodology for automatic disease detection and monitoring in calves (**Fennell** & **Talas**, EPSRC Innovation Fellowship £610k);
- Turing Fellowship on creating an open research data platform from the world's most intensively monitored dairy farm for tackling One Health grand challenges (**Dowsey**).

1.3. Research communities

The core remit of our research communities is to provide the environment where interdisciplinary collaborations flourish and staff can align with multiple, appropriate communities. Community leads have a remit and budget to develop joint initiatives with theme leads to drive effective research delivery by:

- maintaining an outstanding training environment for staff and students through a series of regular events (*e.g.* journal clubs, workshops and mingles, away days);
- providing mentorship, role models and support across disciplines for grant and paper writing for earlier career staff;
- coordinating with the other communities and stakeholders in the wider University.

Together with the BVS Research Director and Heads of School, these theme and community leads constitute the UoA6 Research Leadership Team, which meets weekly to discuss and disseminate current research issues and opportunities. Through this we encourage and nurture earlier career staff into community lead roles (*e.g.* **Peachey**, **Mann**, **Hezzell**).

Animal Welfare and Behaviour (AWB) (lead: Mendl)
*Fourteen researchers including 2 early-career (***Fennell***, **Talas***), 2 impact case studies (***Knowles***; **Mullan/Lambton***)*

Bristol's AWB group is internationally respected (Nicol 2019 Animal Welfare). Its external research income of **£7.9m over the assessment period** is from a combination of UK research councils, government departments, charities and the European Union. Its strengths emerge from the integration of fundamental behavioural and cognitive science with applied animal welfare. AWB researchers carry out high quality, fundamental research into animal motivation, cognition and emotion, including development of novel approaches and integration of innovative technology and computational modelling to generate new and better methods for animal welfare assessment. This work includes collaborations with researchers in SoBS (UoA5), Psychological Science (UoA4), and Physiology, Pharmacology and Neuroscience (UoAs 1 and 4). Significant research takes place in livestock and companion animal species (*e.g.* **Held** 2020 Animal Behaviour), but also with laboratory animals, contributing to the development of welfare-based 3Rs refinements (*e.g.* **Mendl** 2020 Current Biology), and of new welfare approaches now used widely in laboratory, companion and livestock species (*e.g.* **Mullan** 2020 Animals). AWB runs 'Bristol Cats', a unique cohort study of health, welfare and behaviour of pet cats throughout their lives.

Key achievements include:

- establishing the BBSRC/UFAW-funded Animal Welfare Research network, led by **Mendl**, first awarded 2016, renewed 2019 (total £238k);
- first demonstration of social buffering in birds, specifically in chickens (**Held**, **Edgar**, **Paul**, 2015 Animal Behaviour);
- pioneering and implementing new 'cognitive bias' methods for assessing affective state as a means of inferring welfare, now widely adopted in animal welfare research, and increasingly by psychopharmacologists and neuroscientists in human research (**Mendl** 2014 Behavioural Brain Research; **Mendl**, **Paul** 2020 Neuroscience and Biobehavioral Reviews);
- using computational modelling and meta-analyses to provide deeper understanding of links between affective state and decision-making in cognitive bias tasks (**Mendl**, **Paul** 2020 Scientific Reports);
- dissecting links between physiological arousal and decision-making in chickens (**Nicol** 2015 Scientific Reports);
- first demonstration of 'emotional fever' in fish with implications for the phylogeny of animal consciousness (**Knowles** 2015 Proc Royal Soc B);
- first demonstration of transgenerational effects of neonatal experience in sheep (**Mendl**, **Murrell** 2014 Biology Letters);
- identifying the high prevalence of keel fractures in laying hens, modelling collisions to detect causal factors, and approaches to minimising this widespread welfare issue (**Tarlton** 2018 PloS One);
- leading the way in implementing scientific findings through legislation, assured standards, knowledge transfer, and social science approaches to human behaviour change, to improve animal welfare in the UK, Europe and developing countries (**Mullan** 2014 Trends in Food Science and Technology; ICSs **Knowles**; **Mullan**, **Lambton**).

Infection, Inflammation and Immunotherapy (I3) (leads: Peachey, Mann)
*Fifteen researchers including 2 early-career (***Peachey***, **Vidana Mateo***)*

Direct income to UoA6's I3 researchers totalled **£5.1m during the assessment period** from a combination of UK research councils, government departments, charities and the European Union. I3 research in UoA6 is closely linked with Bristol One Health through the EBI, and with UoA1's immunology and cancer biology groups (shared laboratory facilities: UoA6 PIs **Wooldridge**, **Mann**). Researchers maintain close links with Bristol-PHSI (mathematical modelling, costs of health interventions; joint appointments **Dowsey**, **Turner**, **Brooks Pollock**), the Infection and Immunity network and the Cancer network, and members of I3 sit on the relevant steering groups (**Reyher**, **Turner**, **Gibson**). Our farm animal research engages with the national Food Security agenda through the Cabot Institute. Research areas contributing to this synergy include: immunology, microbiology, mathematical modelling, companion animal infectious diseases and veterinary parasitology. The excellence and interdisciplinary nature of our I3 research is evidenced by our critical involvement in the national response to COVID-19 (section 4).

Key achievements include:

- mathematical modelling of the spread of bovine tuberculosis to demonstrate the importance of cattle movements and impact of control strategies (**Brooks Pollock** 2014 Nature);

- development of an iron-responsive probiotic strain of *Streptococcus thermophilus* with anti-inflammatory effects and veterinary and medical applications (following a patent in 2018, Ferryx Ltd, a UoB spin-out company, was incorporated in 2019 to commercialise this strain - **Cogan** 2017 Beneficial Microbes);
- demonstrating the role of early-life rearing environment in development of the immune and metabolic systems in neonates, a basis for the development of nutritional interventions (**Bailey** 2015 ISME Journal);
- demonstrating the impacts of climate change on survival and transmission of infections (**Morgan** 2016 Global Change Biology);
- identifying a mechanism whereby new strains of the human and cattle pathogens *Trypanosoma brucei* and *T. congolense* are generated (**Gibson** 2014 Current Biology);
- developing strategies to identify inappropriate targets for high affinity T-cells in autoimmunity and immunotherapy (**Wooldridge** 2018 Molecular Therapy);
- advising Government and UKRI during the COVID-19 pandemic through membership of SPI-M, SPI-B (**Brooks Pollock**), BBSRC COVID award panels (**Bailey**) and submissions to SAGE (**Turner**).

One Health AMR (lead Reyher)

*Ten researchers including 3 early-career (***Escobar***,* **Fennell***,* **Talas***), 1 impact case study (***Reyher***)*

Research on AMR has become increasingly multidisciplinary across the University of Bristol during this REF period (*e.g.* microbiology, chemistry, veterinary, medical and social science; collaborations with UoAs 1 and 2). External research income to members of this community in UoA6 was **£1.3m during the assessment period** (plus a further £2.8m in awards returned in UoA1). The majority of this was since 2017 and income is on an upward trajectory, demonstrated by the most recent award of **£989k** (**Reyher**, 2019). In addition, UoA6 researchers are co-applicants on external awards from HDR-UK in the area of AMR returned in UoA1 (£2.8m, UoA6 PI **Turner**). The AMR community in UoA6 focuses on decreasing antimicrobial use while improving animal health. Research includes collaborations within 'Bristol AMR' (the cross-faculty research network supported by EBI) and with social science researchers at UoB and the University of Exeter. The group is involved in influencing medicines use UK-wide and in national control programmes on farms.

Key achievements include:

- enrolling and engaging farmers in establishing policy around antimicrobial use, spreading good practice by peer-to-peer sharing of experiences (**Reyher** 2016 Zoonoses and Public Health; **Reyher** 2017 PLoS One);
- demonstrating that ceasing the use of the highest priority, critically important antimicrobials in dairy cows does not adversely affect production, health or welfare parameters (**Reyher**, **Dowsey** 2018 Veterinary Record);
- demonstrating that veterinary prescription records most accurately reflect the dairy industry's antimicrobial usage (**Reyher**, **Dowsey** 2019 Veterinary Record);
- formulating antimicrobial use metrics for UK dairy and beef industries (**Reyher** 2018 Veterinary Record);
- demonstrating the usefulness and applicability of Motivational Interviewing as a tool for improving communication between veterinarians and farmers (**Reyher** 2020 Veterinary Record);

- demonstrating carriage of CTX-M in cattle-associated *Escherichia coli* and the resulting implications for surveillance and farm-to-human transmission (**Reyher**, **Cogan, Turner** 2021 Applied and Environmental Microbiology);
- engaging with suppliers, retailers, veterinarians, software development companies, livestock farmers and livestock industries, advising nationally and internationally (section 4);
- outreach activity including multiple appearances on national television and radio programmes and as an expert panel member for a Science Media Centre briefing on AMR in agriculture (**Reyher**).

Veterinary Clinical Research (lead Hezzell)
*Six researchers including 2 early-career (***Garcia da Noiva, Hezzell***)*

The future development of the evidence-base to optimise animal health depends on integration between veterinary clinicians and researchers in animal and human health and disease. Clinical research has received **£1.6m in external funding over the assessment period** from a combination of UKRI, charities and industry. UoB's wholly owned subsidiary, Langford Vets (LV; section 3), has increased first opinion and referral caseload, and driven increased collaboration in clinical research between LV and UoB colleagues in UoA6. University clinical research staff are now able to focus on fundamental research relevant to their clinical expertise (*e.g.* **Hezzell's** work on mechanisms of arrhythmias): although not REF-eligible, LV staff continue to be active in research focussing directly on improving the diagnosis and treatment of veterinary patients (39 and 38 papers with LV staff as authors in 2018/2019). This expanded caseload has provided funding through which infrastructure and clinical research can be delivered: the allocation of the Clinical Research Fund (£20k/year), derived from LV income (currently £16.9m/year), funds pilot clinical studies in preparation for major grant applications, and is overseen by a committee including both LV and BVS research staff. To maximise the integration between clinical veterinary practice, research and teaching, Hammond was appointed as joint Head of BVS and CEO of LV in 2016: this appointment has further improved collaboration between the academic and commercial arms of the structure, and now provides opportunities for cohort studies and controlled clinical trials (average of 5.2 joint LV/UoB publications/year before Hammond's appointment; 11.2 publications/year since). 'Bristol Cats' (**Blackwell**) was one of the first animal cohort studies in the UK, while 'Generation Pup' is now a large, ambitious, multicentre cohort study. UoB staff are also active in the UK multicentre Small Animal Veterinary Surveillance Network (SAVSNet, **Sánchez-Vizcaíno Buendia**, **Hezzell**), publishing as lead authors.

Key achievements include:

- demonstrating the mechanism by which arrhythmogenic events are triggered in failing heart cells (**Hezzell** 2020 PNAS);
- development of methodology for the passive surveillance of ticks, an important public health concern, using companion animal electronic health records (**Sánchez-Vizcaíno Buendia** 2017 Epidemiology and Infection)
- amino acid changes in the spike protein of feline coronavirus correlate with systemic spread of virus from the intestine rather than with the infectious peritonitis form of the disease (**Tasker** 2014 Veterinary Research);
- risk of feline coronavirus infection is associated with polymorphisms of the host interferon-gamma gene (**Blackwell** 2020 Pathogens);

- demonstrating associations between arrhythmias, exercise-associated upper respiratory tract obstructions and exercise test conditions in poorly performing Thoroughbred racehorses (**Allen** 2020 Equine Veterinary Journal);
- demonstrating the long-term and trans-generational impact of routine, painful procedures in lambs (**Murrell**, **Mendl** 2014 Biology Letters);
- electrophysiological characterisation of central sensitisation in canine spontaneous arthritis (**Knowles** 2018 Pain: BBSRC £420k).

As LV and BVS have grown since 2016, it has become clear that additional leadership is required. Although outside the REF period, Parkin (research area equine epidemiology) was appointed Head of BVS in November 2020, with a remit to expand the research base in the school, with Hammond retaining and expanding his role as CEO of LV.

1.4. Support for research development and impact

The Research Leadership Team, Research Committee (with student, early career researcher (ECR) and EDI membership) and dedicated Research Support and Development (RSD) manager, develop and oversee processes to enhance the research ethos and environment, including:

- an internal grant review and grant submission support service, including assistance with regulatory issues (ethics, safety), facilities use (Langford and Bristol) and finance;
- the recently introduced online portal and calendar;
- matchmaking support for brainstorming novel research ideas, reviewing manuscripts and supporting the direction of strategic research programmes;
- continued grant writing workshops;
- a weekly research bulletin with specialised news, outputs, event and call notifications;
- reinforcing the research mentoring system, including mentors outside UoA6 to foster cross-disciplinary working and for focussed support for Fellowship applications;
- regular ‘research mingles’ where the RSD actively encourages all graduate students and staff to present short accessible talks;
- a seminar series at which internal and external researchers present their work.

The RSD manager works with Finance to provide the Research Committee with information relating to grants and provides researchers with general advice. The RSD manager also monitors and distributes relevant information from UoB’s URIs (REF5a).

Impact-generation is championed by BVS Impact Director **Tarlton**, benefiting from his role as Faculty Partnerships Fellow, and BVS Industry “Champion” (**Lambton**), who works to capture industry research needs and matchmake with appropriate UoA6 research expertise. Moreover, **Dowsey** has been appointed to a Faculty-level role as co-Director of Enterprise and Innovation. A dedicated Communications Manager coordinates strategic dissemination activity between researchers, industry, government and the public. Impact-generation is also supported by the creation of a UoB Translational Research Hub (TRH) within UoB’s Research and Enterprise Development (RED, see REF5a) division to support health and life sciences research across Main Panel A. Oversight of TRH is through a Steering Group chaired by Iredale as PVC and including EBI’s Advisor on Business Development and Royal Society Entrepreneur-in-Residence, Dr Richard Seabrook (formerly Wellcome Trust Head of Business Development). It currently comprises 8 FTE staff, an increase of 6 FTE during the current REF cycle. TRH provides a single entry-point for all

researchers to translate health and life science-related research to simplify engagement. It also provides a simplified point-of-contact into UoB for companies to explore engagement, commercialisation and collaborative research opportunities. TRH has overseen £5.7m of devolved portfolio funding received during the current REF cycle (MRC Confidence-in-Concept (£2.2m cumulatively) and Proximity-to-Discovery (£600k), Wellcome Trust iTP Award (£800k) and UKRI Impact Acceleration Award and Flexible Talent Mobility Award), which has been strategically deployed to support the translation of health and life science research. In total, UoA6 staff have accessed £144k of combined FTMA/IAA funding during this REF period.

1.5. Achievement of major strategic aims from REF2014

The strategic aims identified in 2014 [and the principal ways we have achieved them] are to:

- build on existing research strengths, specifically developing new methods of assessing animal pain and welfare [AWB have developed novel fundamental (*e.g.* cognitive bias testing) and applied (on farm welfare assessments) approaches];
- use emerging technologies to develop novel veterinary biomarkers, *e.g.* for immune status in pigs and for mycotoxicosis in cattle [**Dowsey's** appointment, bringing expertise in metabolomics analysis, has strengthened this area];
- upgrade existing facilities and build new ones [*e.g.* the Translational Biomedical Research Centre (TBRC) at Langford; the Biological Sciences building; our highly instrumented poultry facility for industry-relevant research funded by CIEL; the John Oldacre Centre, in development to similarly instrument our dairy farm (section 3)];
- overcome the challenge in supply of internationally excellent researchers in animal health and disease by:
  - developing new research strengths, specifically advanced mathematical models to study spread of veterinary infectious diseases (appointments of **Brooks Pollock**, *M. bovis* modelling, and **Sanchez-Vizcaino Buendia**, small animal disease surveillance);
  - bespoke training and support, nurturing ECR promise into established independent academics *e.g.* **Edgar**, former BBSRC Future Leader Fellow;
  - making strategic appointments across discipline boundaries to build team science for tackling global One Health challenges (*e.g.* **Escobar-Tello**, social geographer, **Mann**, HIV vaccinology, **Talas** & **Fennell**, EPSRC Innovation Fellows joint with Computer Science);
  - extending strategic partnerships such as with Rothamsted Research North Wyke farm platform (two further joint appointments: **Takahashi**, **Enriquez Hidalgo**).

1.6. Strategic overview for the next 5 years

We will address the fundamental problems in developing 21st century research on animal health, resilience, welfare and disease. We will make increasing use of joint appointments, shared laboratory space, innovation and enterprise development expertise, and joint funding applications aligned with UoB's research institutes and key institutional strengths: the current SARS-CoV-2 pandemic has clearly demonstrated the value of this interdisciplinary approach. Researchers will increasingly access the most appropriate, leading-edge technologies to answer their research questions and the optimal pathways to impact. The development of an increasingly collaborative environment will:

- focus the existing themes and communities onto new technologies;
- normalise UoB's culture of team science through development of capacity and of the training environment for all staff and graduate students;
- promote the flexibility of our research environment to respond to new challenges.

Developing integrated fundamental and clinical research infrastructure is key to 'One Health'; we will build, support and sustain this infrastructure, leveraging expertise across the University of Bristol through coordination of strategic, high-value grant applications with matched-funding contributions. This will include:

- development of academic clinical staff by creating Clinical Research Fellowships and by engagement with the Wellcome Trust-funded GW4 Clinical Academic Training programme (GW4-CAT), which brings together the Universities of Bristol, Cardiff and Exeter in developing the next generation of clinical academics (first veterinary graduate accepted onto the programme in 2018, supervised by **Wooldridge**);
- support for clinical trials and cohort studies, through collaboration with the UKCRC-registered Bristol Trials Centre (UoAs 1 and 2);
- bio-data-banking, a planned, strategic approach to collection and storage of clinical material and appropriate metadata important for clinical and fundamental research questions, *e.g.* recent decisions to collect routine faecal samples from dairy herds and to store bacterial isolates from AMR assays, contributing to the rapid growth of our AMR research.

2. People

Our strategy is to recruit, retain and develop the very best PhD candidates and promising ECRs into outstanding established scientists. We have a well-established, mentored, training track for both clinical and fundamental scientists, supported by externally competitively funded and internally funded schemes including our clinical academic training.

2.1. Recruitment strategy

All appointments are planned against our research strategy: recruitment is used to develop areas of opportunity that substantively enhance existing UoB strengths in thematic areas and in research infrastructure, with the aim of improving critical mass for multidisciplinary, large-scale and programmatic grant applications. During this assessment period, the Research Leadership Team's involvement in all appointments with any responsibility for research has increased. It develops business cases for strategic hiring clusters with school management, supported and coordinated by the Health and Life Sciences Research Strategy Committee, and is also now involved in all recruitment discussions including those with primarily teaching roles, to foster alignment of research, teaching and clinical work. Overall, during the REF period, we have recruited 2 professors, 9 senior lecturers or equivalent, and 11 lecturers or equivalent. The success of this strategy-based recruitment of research posts is evidenced by our most recent cluster of strategic appointments in early 2020 (**Edgar**, AWB; **Enriquez Hidalgo**, global food security; **Mann**, vaccinology; **Talas** and **Fennell**, artificial intelligence).

We have committed to establishing clinical training lectureships enabling early-career clinicians to begin a substantive research programme aligned to the University's flagship Institutes as well as attain clinical specialist status. These posts will be linked to prior, prestigious PhD studentships such as GW4-CAT and offered as proleptic appointments, the first of whom is in the developing area of cancer immunotherapy, linking to expertise in the Faculty of Life Sciences.

2.2. Support, training and supervision of Postgraduate Research (PGR) students

UoA6 is part of the Bristol Doctoral College, which exists to grow, develop, support and quality-assure our thriving and innovative interdisciplinary community of researchers. Additionally, Bristol's success in open competitions for DTPs, particularly those offering interdisciplinary training opportunities (both as a single institute and GW4-partner), offers an outstanding training environment. The SWBio Doctoral Training Partnership is a UKRI-funded, 4-year programme providing training in cutting-edge bioscience and food security research skills, underpinned by training in data science and systems-based approaches. UoA6 staff have received 15 SWBio DTP studentships and our policy encourages ECR staff to apply for studentships co-supervised with senior staff. UoA6 staff have received 2 GW4-CAT studentships (lead Iredale UoA1, Wellcome Trust, £5.1m, unique in the UK by supporting PhDs for Medics, Dentists and Vets), both veterinary graduates: one is still in post, and we have established a postdoctoral Clinical Research Fellowship/proleptic lectureship to help the second develop her independent research. In addition, we have access to the BHF 4-year PhD programme (lead Poole UoA1 £2.5m) and the EPSRC-funded COMPASS Centre for Doctoral Training in Computational Statistics and Data Science (one of 12 EPSRC CDTs awarded to UoB in the 2019 round, co-applicant **Dowsey**).

During the assessment period, UoA6 staff supervised a total of 76 students to complete research doctoral degrees. In line with our research strategy to encourage links with individuals, Schools and Faculties outside UoA6, we have encouraged co-supervision of students with staff in other units where appropriate expertise exists. This involves formal division of supervisory responsibility, such that total supervisory responsibility during the period was 61.8 (FTE) doctoral completions spread amongst a headcount of 35 academic staff. Support and training structures have been developing over the course of the assessment period, driven by local and UoB-wide needs. BVS has two academic Directors of Graduate Studies responsible for admissions and progression, supported by an administrator and 4 postgraduate mentors. A student PGR representative sits on management committees, including the BVS Research Committee, providing a route for feedback.

UoA6 PGR students specifically receive one-to-one inductions, and monthly research 'Mingles' are well attended by them. Attendance has increased during the COVID-19 lockdown periods, as we have moved to video-conferencing, and we intend to maintain and expand the use of video links. Reciprocal arrangements have enabled access to other relevant research seminar series for UoA6 PGR students, facilitated by this expanded use of video links and by a new, subsidised UniBus route linking the two campuses directly. BVS also funds social events for Langford PGR students.

Since REF2014, UoB has led key initiatives designed to reverse a widely-acknowledged decline in veterinary research, notably: recruitment of 'veterinary' postgraduate students through the award of the BBSRC UK veterinary summer studentship programme (STARS), which funded 16 veterinary research studentships per year open to all UK veterinary undergraduates and holdable at any UK university; the annual, national, veterinary undergraduate research conference; and a national veterinary research mentorship scheme. BVS was the first UK veterinary school to receive a

Wellcome Trust INSPIRE award through the Academy of Medical Sciences, now in its third iteration (lead **Wooldridge**, awarded 2020) and collaborates widely with GW4 and other medical schools (Cardiff, Exeter, Plymouth) and other INSPIRE schemes. **Wooldridge** is co-PI on the €2.34m, EU-funded EN-ACTI2NG training network for PhD students, awarded 2017 and aimed at improving tumour-specific immune receptors (£273k to UoA6).

2.3 Staff development, progression and promotion

Integrity and reproducibility of research is a theme across the Faculties of Health Sciences and Life Sciences. UoB has created an Academic Lead for Research Improvement role, as part of its commitment to formally joining the UK Reproducibility Network (UKRN), in which it already plays a leading role. The Academic Lead (Munafo, UoA1) takes the lead for the following activities to enhance a positive culture of research integrity and improvement across all Faculties:

- providing an integrated training and development programme by embedding this work on research improvement (including research integrity and research culture) within SWBio and other DTPs, for which modular short courses have been developed on topics ranging from data skills to leadership;
- supporting policy framework development especially linking to national activity in this area, including working closely with the UKRN (Cuthill, UoA5, has been integral to the development of national policies for animal use in research);
- ensuring dedicated expert academic and research professional support and mentoring at all career stages, including support for UKRN Local Networks;
- assessing the current issues that may lead to academic staff feeling pressured into taking ‘short cuts’ and considering wider cultural changes;
- through our partnership with ten other UK institutions that are formal members of UKRN we are coordinating a number of institutional statements, including on research transparency and the use of responsible metrics.

UoB’s promotion and progression procedures apply consistent thresholds in a framework that takes account of diversity and inclusion and we use these to support all staff to excel and develop in a team science environment. Within the Schools and Faculties that comprise UoA6, we provide tailored briefing to different staff groups on how best to apply for promotion and progression. Individual discussion and encouragement are provided at regular formal staff development and review conversations and informally as required. School and Faculty leaders proactively identify staff and invite them to apply. We consciously target for support those from under-represented groups including women at Professor and Associate Professor level, and BAME staff at all levels. Heads of Schools work with all applicants to optimise their applications. Recent training in diversity and inclusion is mandatory for all serving on promotion panels, Chairs are asked to highlight issues as they arise, and external (to the Faculty) observers specifically report on this issue at the end of the process. Individual feedback is provided to unsuccessful applicants, with support to improve performance.

To better inform staff on expected performance, and thresholds required for promotion, we have developed an “expectations” document, whereby we are more explicit about the performance indicators expected for Senior Lecturer (SL), Associate Professor (AP) and Professor, taking full account of team science considerations and the varying nature of funding opportunities. In addition, and mindful of the insecurity of funding that many mid-career research-focussed staff

face, we encourage internal, research-active, externally funded staff to apply for core-funded positions where strategically appropriate, in line with the Faculty of Health Sciences 'conversion pathway' to core (that is, research and teaching) posts for research staff with a track record of successful income generation within their research team. During the REF period, we have appointed two such staff to full lectureships (**Lambton**, **Edgar**), as well as promoting 4 staff to professorships (**Whay**, **Tasker**, **Tarlton**, **Lee**), 5 to readerships/APs (**Butterworth**, **Morgan**, **Murrell**, **Reyher**, **Turner**), and progressing 9 staff to SL/senior research fellow positions.

2.4. Equality and Diversity

Our EDI governance structure has been reviewed and strengthened to monitor, evaluate and share activity and progress. We now have 2 Pro Vice-Chancellors with a specific remit for this issue: PVC Research & Enterprise (for staff) and PVC Student Experience (for students). They attend our newly established Inclusion Forum where good practice is shared, achievements celebrated, and common challenges addressed. The UoB Board of Trustees has introduced an Oversight Group to provide assurance around the University's approach to EDI and to enable the Board to better hold the Executive to account for delivery of the University's EDI strategic objectives. Progress is monitored against University-wide Strategic Performance Indicators, for example to: improve UK BAME representation to 8% by 2022/23; increase the proportion of female professors to 33% by 2022/23; and eliminate the gender pay gap in the professoriate (+/- 3%) by 2023. Analysis of quantitative and qualitative (student and staff) diversity data informs activity to better attract, retain and develop groups that are currently under-represented.

There is also a range of action plans and initiatives in place to monitor progress centrally and locally – for example, each Faculty has a committee with specific responsibility for EDI and these are supported by EDI committees at School levels, many of which involve PGRs. The chair of the BVS EDI committee sits on the School Executive Group to ensure that equality principles are considered in all aspects of School decision-making. The committee runs biennial staff surveys to monitor improvement against its action plan and to identify areas that require further action or new issues. Results are presented back to staff. Since 2016, EDI is a standing item on all staff and management meetings.

Progress is also measured through our involvement with external accreditation schemes that recognise best practice in EDI such as the Athena SWAN Charter, Race Equality Charter, Stonewall Diversity Champions programme, and the Disability Confident Scheme. BVS was awarded an Athena Swan bronze award in 2015 (extended due to the pandemic) and is currently applying for silver; SoBS has a silver award (2019). In both Schools, the role of the Equality, Diversity and Inclusion Committee is to embed EDI considerations within management processes and culture to create a robust system that supports an equal, diverse and inclusive environment with the following specific activities.

- Optimising the research environment through:
  - discussing the importance of EDI at research away days;
  - ensuring that everyone is formally trained in diversity and inclusion and minimising unconscious bias;
  - tailored advice and support for those with caring responsibilities during COVID-19, together with University-wide policies to minimise any adverse impact of caring responsibilities on promotion and progression;

    - formal training in “team leadership” responsibilities for research group leads.
- Promoting positive role models from traditionally under-represented groups through:
    - actively including diverse speakers in ECR events and our seminar programmes (for example, in 2019/20 76% of BVS seminar speakers were female);
    - considering gender balance on PGR supervisory and progression committees (being careful not to overburden women and those from BAME backgrounds).
- Tailored support for female ECRs through:
    - proactive encouragement of grant writing, including those for personal fellowships;
    - “bootcamps” and internal peer review to optimise grant/fellowship success rates;
    - proleptic appointments for successful fellowship applicants;
    - encouragement and support for leadership development either through GW4 or nationally *(e.g.* AURORA, **Hezzell**) and locally [UoB schemes, *e.g.* Bristol Senior Leaders (**Hezzell**, **Reyher**, **Tasker**, **Whay**), Stepping into Leadership (**Escobar-Tello**)];
    - engagement with University-wide “women’s mentoring” schemes (*e.g.* **Reyher**, promoted to Reader/Associate Professor during this REF period, **Held**, **Hezzell**)
- Encouraging senior women to increase their national profile through membership of grant committees, REF panels and other relevant bodies, and allocating specific time for them to do so. For example, **Wooldridge** was specifically encouraged to apply for membership of the **UoA6 REF subpanel**.

Veterinary undergraduates and professionals have one of the largest gender gaps of any career group (79-84% female undergraduates through the assessment period), and representation of BAME groups is low. This gender ratio has been slow to work through to academic staff. Although there have been more women than men at Research Associate to Senior Lecturer/Reader/Associate Professor grades in BVS up to 2020, there were still more male than female Professors. However, the number of male Professors has remained stable at between 10-12 while the number of female Professors has increased from 3 in 2013 to a high of 8 in 2016, although it has decreased since then as a consequence of replacing senior staff with 7 ECRs (of whom 5 are women: **Escobar-Tello**, **Garcia da Noiva**, **Hezzell**, **Peachey**, **Vidana Mateo**). BVS’s goal is to achieve at least 40% female Professors consistently by 2022 (higher than the UoB ‘stretch target’ for 2022/3) by increasing the numbers of females shortlisted for Professorial posts, advertising all positions as flexible working by default, and by implementing Textio analysis to screen advertisements to remove male-biased language. During the REF period we have recruited/promoted 3 female (**Heffernan**, **Whay**, **Tasker**) and 3 male (**Dowsey**, **Tarlton**, **Lee**) Professors.

The outcome of internal progression and promotions procedures suggest reducing gender disparity through this REF period. In BVS there were 15 (12 F, 3 M) successful and 7 unsuccessful (4 F, 3 M) applications over the last 5 years: of successful applications, 7 worked part-time, and the success rate for female candidates was higher (75%) than for males (50%). The percentage of eligible staff applying for promotion/progression was similar for men and women. The pipeline for women to reach chair level currently looks strong, with more women than men at SL/Reader/AP level in 2020, better reflecting the School’s gender balance. Commensurately, the gender balance of staff in this submission includes 51% women, compared with 36% in 2014. Holders of senior academic posts in BVS are balanced (7 women, 8 men in 2020) and include strong female role-models (**Reyher**, **Hezzell**). Similarly, the proportion of submitted staff who are from BAME backgrounds has increased from 6% to 11%, although still not in line with the UK national population statistics of 13.8%.

3. Income, infrastructure and facilities

3.1. Income

Total UoA6 research spend during the assessment period was £18.9m (REF4b). As described above, there was a strategic realignment of research activity during this cycle, refocussing research funding from small charities to UKRI sources. This has been associated with an increase in funding per FTE from £70k to £84k per year, even with a modest decrease in FTE, attesting to the success of our strategic approach and positioning us to grow sustainably.

Highlights of awards during the REF period include:

- BBSRC/NERC/Argentina. FARMS-SAFE: Future-proofing AMR risk management surveillance and stewardship in the Argentinian farming environment (**Reyher**, **Escobar-Tello**), UoA6 £987k;
- MRC. AMR in Thailand (**Reyher**, **Turner**), total £2.9m, UoA6 £225k;
- NERC/MRC/BBSRC. One Health selection and transmission of AMR (**Reyher, Cogan, Turner**), total £1.2m, UoA6 £521k;
- ESRC. Diagnostic innovation and livestock (**Reyher**), total £1.4m, UoA6 £446k
- BBSRC LoLa. Understanding influenza A virus: linking transmission, evolutionary dynamics, pathogenesis and immunity in pigs (**Bailey**), total £4.4m, UoA6 £725k;
- BBSRC / MRC Methodology Panel awards for computational methodology in translational proteomics (**Dowsey**), UoA6 £974k;
- European Centre for Disease Control. Mathematical modelling and economic evaluation (**Brooks Pollock**, **Turner**). UoA6 projected £648k;
- NERC/AHRC/Colombia. Towards environmental reconciliation in páramo land in Boyacá: resolving ecosystem trade- offs in posts-conflict spaces (**Escobar-Tello**, **Eisler**), total £1.1m, UoA6 £556k;
- EPSRC Innovation Fellowship award (**Fennell**, **Talas**), UoA6 £610k;
- BBSRC. Studies of animal affective state (**Mendl**), UoA6 £974k;
- Racing Foundation (**Mullan, £687k**) and the Horserace Betting Levy Board (**Allen, £216k**), funding for equine clinical/welfare research.

3.2. Infrastructure and Facilities

The largest administrative group in this submission, BVS (Faculty of Health Sciences) sits on a site of approximately 300 acres. It has state-of-the-art on-site laboratory and experimental animal facilities and access to all the necessary core equipment locally or through facility access in Bristol. Clinical facilities for research and teaching are delivered through a University-owned commercial company, Langford Vets (LV, current turnover £16.9m pa), and facilitated by joint appointments (*e.g.* Hammond). Clinical expertise includes companion animals (including equine) and farm animals, imaging and diagnostic facilities (including two MRIs and world-leading molecular diagnostic labs, established by Helps and included as one of our 4* impact cases in REF2014). Its dairy and sheep farm of approximately 250 acres maintains 180 cows and 100 sheep. BVS also maintains a post-mortem facility for clinical service, teaching and research purposes and a fully licensed, low-throughput abattoir, also supporting research and teaching.

The School of Biological Sciences (SoBS, Faculty of Life Sciences) also contributes significantly to UoA6 research. SoBS is housed in a new, £63.8m Life Sciences building opened in 2015), accompanied by advanced facilities for genomics/bioinformatics/computing (£2m), and for plant growth (GroDome, £1m). SoBS maintains large, active research groups in: Plant and Agricultural Sciences; Behavioural Ecology and Sensory Biology; and Ecology, Environmental Change and Evolutionary Biology (all UoA5). Links between BVS and SoBS research in livestock and crop sciences are maintained through active, funded collaborations and shared laboratory space (**Gibson**, **Bailey** 2018 PLoS Pathogens; 2015 PloS NTD; 2014 Current Biology), shared membership of Cabot, and shared links with Rothamsted Research.

Centre for Innovation Excellence in Livestock (CIEL) poultry facility

During this REF period, collaboration between government, industry and academia created four Agritech centres to promote greater efficiency, resilience and wealth across the agrifood sector. UoB is one of 12 academic partners involved in CIEL, with £650k investment from CIEL matched by £500k from UoB. CIEL has established a new, state-of-the-art poultry facility capable of replicating conventional poultry farm facilities, but with unparalleled ability to monitor environmental characteristics (temperature, gases) and bird behaviour. This unit was tested in 2018 and became operational in 2019, one of the first CIEL-funded units to do so; it has contributed to the ability of the AWB group to perform industry-relevant poultry welfare research.

Containment level 3 aerobiology suite

As part of UoB's response to COVID-19, the existing aerobiology suite was refurbished in 2020 at a cost of £18k. Seventy-seven square-metres are now at full SAPO ACDP containment level 3 (easily convertible to SAPO level 3) with upgraded air-handling and space for laboratory and animal experiments. This suite is now live for studies of survival of SARS-CoV-2 in aerosols as a collaboration between **Cogan** and **Mann** with Finn (UoA2) and Reid (UoA8). This contributed to a £0.5m NIHR study of droplet spread in clinical areas including theatres (Maskell UoA1, Reid UoA8).

John Oldacre Centre and North Wyke

The £1m John Oldacre Foundation fund is instrumenting Wyndhurst dairy at Langford to create the John Oldacre Centre for Sustainability and Welfare in Dairy Production. This development is taking place in collaboration with the Rothamsted Research North Wyke Farm Platform, the most instrumented beef unit in the world, with the UoB Sensor Platform for Healthcare in a Residential Environment (SPHERE, £15.3m from EPSRC), and with methodology funding from the Alan Turing Institute (**Dowsey**). It will bring together our strengths in activity and behaviour monitoring, life-course epidemiology, machine vision and data science, animal welfare, food security, AMR and sustainable farming to create a resource that will enable research on the development and early detection of disease and welfare issues, disease transmission, the effectiveness of interventions, and data analytics/sensor technologies in both animal and human realms.

ASU research animal accommodation

Experimental animal accommodation at Langford provides containment facilities for working with large animals to ASPA standards. It provides environments to carry out controlled intervention and/or infection experiments complementary to industry-relevant,

farm-based facilities such as CIEL and the dairy farm. It includes long-term facilities for monitoring surgical implants as well as containment facilities suitable for faecal-orally and aerosol transmitted organisms (HEPA-filtered in- or out-flow). Work with infectious diseases including Campylobacter, Salmonella, Cryptosporidium, influenza virus during the assessment period has been funded by Defra, FSA, BBSRC, and the Gates Foundation.

Translational Biomedical Research Centre (TBRC)
Large-scale research funding (MRC, £2.77m; BHF, £1m; UoB, £2.6m) has established TBRC to perform ASPA-regulated sheep, pig and rabbit research on site. TBRC was established as one of only two state-of-the-art large animal research facilities in the UK: it includes a 3T MRI and a fully equipped catheterisation lab for experimental surgery studies. Research income generated across UoB by access to TBRC is £3-4m annually. Members of the AWB, I3 and clinical research groups are involved both in the steering group and in the research activity in TBRC, although this is predominantly returned in UoA1. The facility provides the potential for continued development of the pig as a preclinical transplantation model and for behavioural studies using fMRI in conscious dogs.

The Langford abattoir
UoB is unique in Europe in maintaining a commercial abattoir and has recently funded a £100k refurbishment to maintain its activity. Since a significant part of its costs is covered either by its commercial or teaching activity, it has been able to support livestock research (cattle, sheep, pigs) by members of the Global Food Security theme and I3 community, either to recover samples from ‘normal’ animals, or to process experimental animals.

Langford Vets (LV)
BVS delivers its clinical teaching through the wholly owned subsidiary, LV, which has driven an increase in caseload and improved infrastructure and pump-priming funding for clinical research (annual income £8.7m in 2014 growing to £16.9m at the end of the REF period). We are in discussion with the Home Office over inclusion of areas within the clinical hospital on the University ASPA establishment licence to support cohort studies and clinical trials.

Bristol Zoo
Bristol Zoo contributes to the Global Wildlife and Conservation MSc, co-supervising research projects with UoA6 staff (8 papers, **Turner**, **Knowles**, **Rooney**). We are working closely with the zoo to jointly shape the future collaboration.

Other UoB institutional facilities
UoA6 staff make use of and are closely involved with many of the other institutional facilities, including the Genome Centre and the WT/GW4 Wolfson Bioimaging Centre, both of which have received investment during the period (£2m and £2.5m respectively).

4. Collaboration and contribution to the research base, economy and society

A key aspect of our ongoing research strategy is to fully engage beyond our own disciplines to maximise our research's impact and reach. Centrally, this has been facilitated by the formation of strategic, interdisciplinary University Research Institutes (URIs) and by launching the GW4 Alliance between Bristol, Bath, Cardiff and Exeter Universities. Within UoA6, staff have used these URIs and local resources to engage with industry, policymakers, funders, and the academic community.

4.1 University Research Institutes (REF5a)

The Elizabeth Blackwell Institute for Health Research (EBI) aims to identify and nurture new opportunities for interdisciplinary research, in particular by exploiting expertise in the non-medical faculties and translating that research into effective One Health outcomes. EBI includes key partnerships with bio-pharmaceutical companies, local hospitals and health groups. Supported by Wellcome Trust strategic support funding (£3.75m Wellcome ISSF, matched with £3.75m from UoB), the MRC Confidence-in-Concept (£1.8m) and Proximity to Discovery (£600k), EBI offers pump-priming funding to develop interdisciplinary and translational research and provides routes for ongoing recruitment and development of new researchers, initiating partnership activities and outreach events. In the current REF period, EBI funded a total of 240 projects, including 79 fellowships for ECRs (8 in Bristol Veterinary School). From the beginning of the COVID-19 pandemic, EBI responded rapidly, focusing resources onto rapid-response research; through a bespoke panel (members included **Brooks Pollock**, **Turner**), it funded more than 80 Rapid Response COVID-19 projects, 3 led by UoA6 staff (**Brooks Pollock**, **Wooldridge**) and 5 others involving UoA6 co-investigators (**Turner**, **Cogan**, **Mann**, **Bailey**). EBI was instrumental in rapidly establishing the University's COVID Emergency Research (UNCOVER) group to understand and combat the many health and societal challenges raised by COVID-19. UoA6 staff are co-leading key research strands in cellular immunology (**Wooldridge**), aerosol biology (**Cogan**) and preclinical vaccine development (**Mann**). EBI supported a week-long online networking event focusing on COVID-19 research (co-organiser **Turner**) and hosted a public event with postgraduate researchers to focus on the future of health research in the context of the pandemic.

The Cabot Institute for Environmental Research (Cabot) carries out fundamental and responsive research on risks and uncertainty in a changing environment (339 scientists across the University working in a range of environmentally focused areas including food security). Cabot provides infrastructure for researchers to actively engage (*e.g.* via workshops) with policy makers, marine industries, fisheries scientists and conservation groups through links with (among others): Defra, the International Union for Conservation of Nature, Environmental Technology and Service Companies, the International Council for the Exploration of the Seas, and the Institute of Marine Engineering Science and Technology. Research interests include climate change, natural hazards, food, water and energy security, and future cities. This distinctive approach fuses rigorous statistical and numerical modelling with a deep understanding of interconnected social, environmental and engineered systems, past, present and future. To achieve its vision, Cabot stimulates linkages across disciplines and with industry and government, developing partnerships, enhancing knowledge exchange across sectors and building groups of shared interdisciplinary expertise. The Cabot Food Security theme includes many UoA6 staff including **Eisler**, who led the theme between 2012 and 2016.

The Jean Golding Institute (JGI) for data-intensive research supports multidisciplinary research in data science and AI and to build collaborative relationships with external organisations in response to the AI and Data Grand Challenges set out within national and local industrial strategies. UoB has nurtured the Bristol AI ecosystem significantly over the past 4 years; UoA6-relevant evidence includes collaborations with the International Livestock Research Institute (ILRI), international twinning with the Data Science Centre, Strathmore University (Kenya) on rural analytics, and a key formal partnership with the Alan Turing Institute. UoB identifies AI, Data Science and Digital Health as areas of strategic research growth; investments since 2016 consist of four new professorial positions in AI and data science including **Dowsey**, who is a founding member of the JGI steering group, Turing Fellow, and with **Eisler** and partners ILRI, hosts a Turing PhD studentship.

4.2. Engagement with Industry

BVS appointed a Business Fellow (later Partnerships Fellow) in 2015 to support developing contacts between staff in UoA6 and relevant industry (**Tarlton**). This is a Faculty role and was extended to cover partnerships with industry, academic, local government and social groups (*e.g.* Rothamsted Research, Local Government and the Woodland Trust). The role represented the School and Faculty on the Strategic Alliances Review Board (chaired by PVC Research and Enterprise), and later the University Partnerships Committee. This role continues, ensuring continued involvement by UoA6 staff. A further business 'champion' for UoA6 (**Lambton**) has been appointed to maintain local engagement with industry and works with CIEL. Industry research income in UoA6 has risen during the assessment period (£25k in 2014/5; £139k in 2019/20; total £455k during the assessment period). Other achievements include:

- funded research collaborations with Folium Food Science, Dechra Veterinary products, the Foundation for Food and Agricultural research (FFAR), Boehringer Ingelheim, Anpario, ORF Genetics, Raft Solutions, Zoetis, MSD, Agri-EPI Centre, Quant Foundry and Aviagen;
- extensive engagement with LV and ten local commercial veterinary practices as well as incorporating research into continuing professional development nationally and internationally through the British Veterinary Association, British Cattle Veterinary Association and others;
- engagement with producer groups (*e.g.* Waitrose Dairy Farmers, Welsh Lamb & Beef Producers, Royal Association of British Dairy Farmers, National Farmers Union), retailers (Sainsbury's, Tesco, Waitrose, Morrisons, the Co-operative group) and consumer groups. Since 2015 UoB has hosted retailer events annually, most recently supported by Winterbotham Darby, to showcase translation of research into the supply chain.

4.3. Impact on Policy

- In 2016 UoB formed PolicyBristol to facilitate implementing research into policy. UoA6 staff have worked extensively with PolicyBristol. Examples include policy briefings and workshops with Defra (animal welfare, farmer facilitation), parliamentary POST notes (antimicrobial usage, transmission of AMR) and evidence submissions (future farming policy) along with international briefings (sheep and goat herd health in Botswana and Tanzania).
- In addition to their direct funding for research, UoA6 staff are regularly consulted by government, non-governmental organisations and charities with responsibility for

agriculture, including Defra, AHDB, RSPCA, Soil Association, Red Tractor, Dairy UK, BVA, BCVA and NFU (**Reyher**, **Mullan**, **Lambton**, **Bailey**). Their activities include contributing to policy development and membership of advisory and standards panels.

- UoA6 staff have engaged with Government advisory panels, including the: Scientific Pandemic Influenza Group on Modelling (SPI-M, SPI-B) (**Brooks Pollock**); House of Lords Select Committee on Animal Welfare and Brexit 2017 (**Mullan**); Government Roundtable on Farming Innovations 2018 (**Mullan**); Defra Committee on the role of grazing livestock 2017 (**Fennell**); Beak Trimming Action Group (**Nicol**, report 2015).

4.4. Global Agricultural Policy

- UoB is one of only 5 UK institutions who are members of the Global Farm Platform (GFP), an international organization working to create networks of researchers focused on sustainable and responsible production of healthy food from healthy animals. Outcomes from the GFP include research on Smallholder Dairy Cooperatives in ODA countries, and BBSRC-funded work on health and welfare consequences of using high-producing dairy cattle in India (**Tarlton**).
- UoA6 staff have engaged with the UK Government GCRF initiative, attracting funding for existing and new collaborations in ODA countries, including Colombia, Brazil, Thailand and Argentina (**Escobar-Tello**, sustainable agriculture and land use; **Mendl**, welfare and health assessments; **Reyher** and **Turner**, antimicrobial usage and resistance).
- Close links with Rothamsted Research are maintained by joint appointments (**Lee**, 2013; **Takahashi**, 2016; **Enriquez Hidalgo**, 2020), resulting in significant joint grant funding (£640k during the assessment period).

4.5. Funding bodies

UoA6 staff have engaged extensively with UKRI funding panels, predominantly BBSRC, including: responsive mode Panel A (**Tarlton**, **Mendl**, **Bailey**); COVID-19 Rapid Response Panel and the Agile Response Panel (**Bailey**); arthropod disease vector funding strategy committee (**Wall**, 2014-2016); Future Leaders Fellowships panel (**Mendl**). Staff have sat on UKRI-BBSRC advisory groups including: Advanced Training Partnership Steering Panel (**Eisler**); Animal Welfare Working Group (**Mendl**); Expert Working Group on animal welfare/sustainable intensification (**Knowles**).

The AWB group lead the BBSRC-funded UK Animal Welfare Research Network, AWRN (**Mendl**). The AWRN aims to bring together the UK animal welfare research community, researchers in related areas and stakeholders with interests in animal welfare, to identify important research topics, foster collaboration, and support and encourage research activities.

Staff have also been members for the: Wellcome Trust Population Health Panel (**Turner**) and Vaccines for AMR panel (**Brooks Pollock**); Royal Society Interview Panel for Dorothy Hodgkin Fellowships (**Mendl**); Arthritis Research UK and Versus Arthritis PhD fellowship and Career Development Fellowship panels (**Tarlton**); and international panels for NIH (**Turner**), Canadian Institute for Health Research (**Mann**), and Norwegian and Swedish Research Councils (**Knowles**).

4.6. Engagement with the academic community

Mendl has received awards from the: RSPCA/British Society of Animal Science (BSAS), 2015; Alice Richie Trust Memorial Fund Award 2014; Universities Federation for Animal Welfare (UFAW: 2014). **Reyher** and the AMR community have received Public Health England Antibiotic Guardian Awards for Research (2019), and for Agriculture and Food (2018) as well as the Veterinary Record's Impact Award (2019) and UK Diagnostic Summit's Highly Commended Award for Research (2019). **Lee** was awarded the Sir John Hammond Memorial Prize by the British Society of Animal Science, 2015.

Staff have given invited plenary talks at national and (over 50) international conferences, *e.g.*: North America (8 plenaries including the Charles River Lecture, American Association for Laboratory Animal Science Annual Meeting 2018; Sustainable and Responsible Livestock Production: Global Farm Platforms 2014); Europe (18 plenaries including the Congress of the International Society for Applied Ethology 2014 and 2016; Digestive Physiology in Pigs 2015); China; Australia and India.

We have acted as journal Editors for: Royal Society Open Source; Journal of Small Animal Practice; Journal of Ethology; Methods in Ecology and Evolution; Ecosphere; Scientific Reports; Agribusiness; Mathematics Today; Proc. Royal Society B; IEEE Journal of Biomedical and Health Informatics; Veterinary Medicine and Science; Public Health; Parasites and Vectors; Infection, Sexually Transmitted Infections; Genetics and Evolution; Veterinary Surgery; Veterinary Medicine and Surgery. Staff have acted as guest editors for special issues of: Proceedings of the Royal Society B; Frontiers in Sustainable Food Systems; Frontiers in Veterinary Science; Animal.